INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
VOL. 14 NO. 2 (2023) 205-213

IJSCET

http://publisher.uthm.edu.my/ojs/index.php/ijscet

ISSN : 2180-3242 e-ISSN : 2600-7959

International Journal of Sustainable Construction Engineering and Technology

Thermal Performance of Horizontal Fixed Sun Shading Device

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DOI: https://doi.org/10.30880/ijscet.2023.14.02.021
Received 16 March 2023; Accepted 16 March 2023; Available online 08 May 2023

Abstract : Earlier investigations on passive cooling methods applied software modelling, and the findings were not confirmed through field measurement. Hence, this study applied a stationary experiment on a real structure and weather conditions employing horizontal sun shading (SDH). The purpose of this study was to compare the performance of fixed passive sun-shading devices put on to the bare façade of three-story terrace shophouses in Malaysia. The experiment findings revealed that SDH significantly improved the internal thermal environment by lowering the average monthly indoor air temperature (Ta) by 0.98 K and the peak temperature by 2.11 K. SDH is also effective during the warmest sunny days, lowering 1.23 K on average for the day. Meanwhile, SDH reduced the temperature in the control room by 5.40 K during the warmest peak time. When it came to indoor mean radiant temperature (Tmrt), SDH performed better than the control room in the very hot peak over a month (2.38 K) and on the highest temperature of the day (7.70 K). Finally, it can be inferred that SDH worked better from late at night until early in the morning, cooling the room temperature faster. This quiescent choice is one of the best for enhancing a building's internal thermal performance while also possibly contributing to a decrease in operational energy consumption.

Keywords: Horizontal shading device, indoor thermal performance

1. Introduction

The creation of an envelope boundary between an exterior and an interior is crucial for thermal control to provide a pleasant, healthy and ideal thermal environment. The retrofitting of facades to reduce energy consumption is a significant move towards a low-carbon construction sector. Sun shading at the facade of a building is widely used as a high-performance building envelope with demonstrated efficacy (Z.Lin et. al 2022). The planning and execution of the building's exterior design affect almost 60% of energy usage in buildings (Ingy et. al 2017). Extensive energy is required to cool the interior area, particularly in tropical climates that are hot and humid all year. Different approaches for passively cooling solutions have been created to handle extreme heat from the sun and heat transfer through the building's exterior. (Wardah F. et. al, 2017). In spite of this, the mere installation of solar protection devices on the exterior of a building has the potential to substantially improve both the thermal environment and the amount of energy that is consumed by the building. (Luca Evangelisti et. al, 2020). The relationship between temperature and heat

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transfer affects the thermal performance of the buildings, which in turn makes it possible for people to feel comfortable while inside those buildings. [Hermawan et al, 2020].

It is necessary to select the passive sun shading design that is the most efficient to have the greatest possible impact on the way the buildings regulate their internal temperature. Sun shading mechanism solutions are foremost important elements for improving the exterior of a building, and they are frequently used as a sun buffer, particularly in tropical countries. The solar screening mechanism method regulates internal thermal performance and visual comfort while giving users control over their privacy and outside view. When designing a sun shading system, one must take into account the following: thermal requirements, daylight transmittance and interior visual impact, reliability, appearance, maintenance, value for money, dependability, user expectations, and other usages. The key goal of a sun shading application is to protect the building over the negative impacts of excessive heat caused by the sun which serves two important functions as a controller: improving a building's efficiency and producing a pleasant environment.

The shading devices that comprise passive sun shading systems embody the non-intrusive design idea. This strategy's main concept is that no energy source is used. The effectiveness of a shading device is impacted by three major parameters: the weather and atmospheric conditions, the natural setting connected with the location, and the design goals. In addition, integration of shading devices together with a hollow area in between or a two-layer façade may improve indoor thermal performance. There is a previous study of research has been carried out in Jordan's hot and dry environment, which differs from the climate of this study, which is in the tropics. The research provides a reference that was carried out and investigated the interior thermal performance of a variety of different kinds of inert sun shading options on a real-scale premises. The results showed that there was a decrease in the indoor ambient temperature ranging from 1°C to 5.75°C (A.A. Freewan et. al, 2014). The climatic component is among the factors that influences the total efficacy of the sun shading installation in terms of producing better levels of thermal comfort inside the building. As a consequence of this, the objective of this research was to conduct a comparative temperature performance analysis to investigate the effectiveness of horizontal sun shading (SDH).

2. Materials and Method

In Malaysia, a shophouse are essentially utilized for business activity on the ground floor and dwelling on the upper floor. However, this purpose has shifted, with the top level now serving as an office or commercial space rather than a dwelling. Nonetheless, the bottom level is still a commercial area. The length of a shophouse, which can be up to 30 meters, is tiered and the building can have two or three stories. In this research, the experiment has been conducted in a shophouse building that are situated on a narrow plot of land, with open parking to the west and south and two-story storefronts to the north.

The similar shophouse units were selected in this investigation. The three-story buildings are situated at Lot 105 and 108, Block A, City Campus, Universiti Tun Hussein Onn Malaysia (UTHM) (Fig. 1). In this research, parallel spaces (10 m2) by each section on the second floor and located at the frontage of the building were chosen. The dimensions, window placements, construction materials and directional orientation of the structure were all comparable among the rooms. Due to the large aperture of the front façade, these spaces were exposed to strong radiation (facing west) and got the most heat radiation. There was no activity of any kind and none of the rooms were inhabited in any way during the entire process of measuring.

Fig. 1 - The installation of horizontal sun shading devices at the 1st floor of Lot 105, Block A, City Campus Universiti Tun Hussein Onn Malaysia

On the outside of the building, one unit with a horizontal sun shading device was placed, while one room was left barren as a control room. The placement of the shading devices employed in this investigation, namely SDH, is shown in Fig. 2. The shading devices were constructed with a width of 150 mm, and 100 mm gaps were left between each panel before being fixed into the wall at a distance of 150 mm from the windows. The sunshade is made of aluminum and coated in silver paint all over its surface. The amount of direct sunlight that enters a structure has the most significant impact on the apertures of windows.

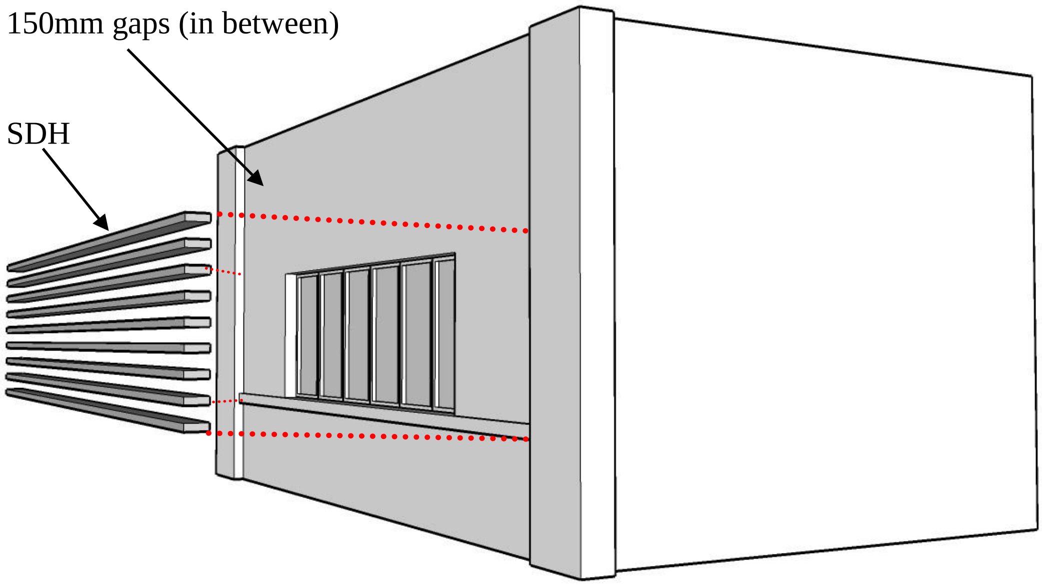

Fig. 2 - Simulation of the construction of horizontal sun shading fixed into the existing wall unit and cover the whole windows

The research carried in one month (1 May – 31 May 2019), with measurements obtained every 10 minutes for 24 hours. This study focused at the results of one notably hot and sunny day and the monthly average. Field measurement was used to acquire data and each room (Fig. 3 and 4) was fitted with a thermal comfort meter (Delta Ohm HD32.3 PMV data recorder) for indoor data gathering. This thermal comfort meter monitored interior air temperature (T_a), globe temperature (T_g), relative humidity (RH_i), air velocity (V_a), Outdoor ambient temperature (T_{ao}), relative humidity (RH_o), and solar radiation. The equipment computed the mean radiant temperature (T_{mrt}) automatically.

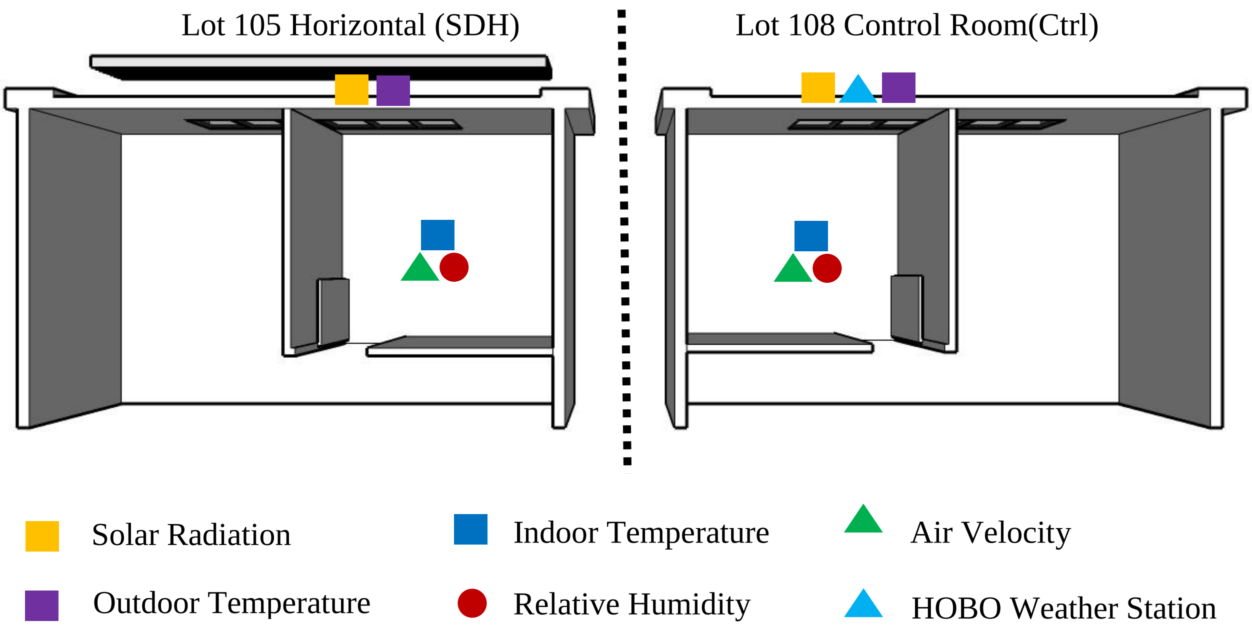

Fig. 3 - Layout of the room area indicating where each piece of equipment is located

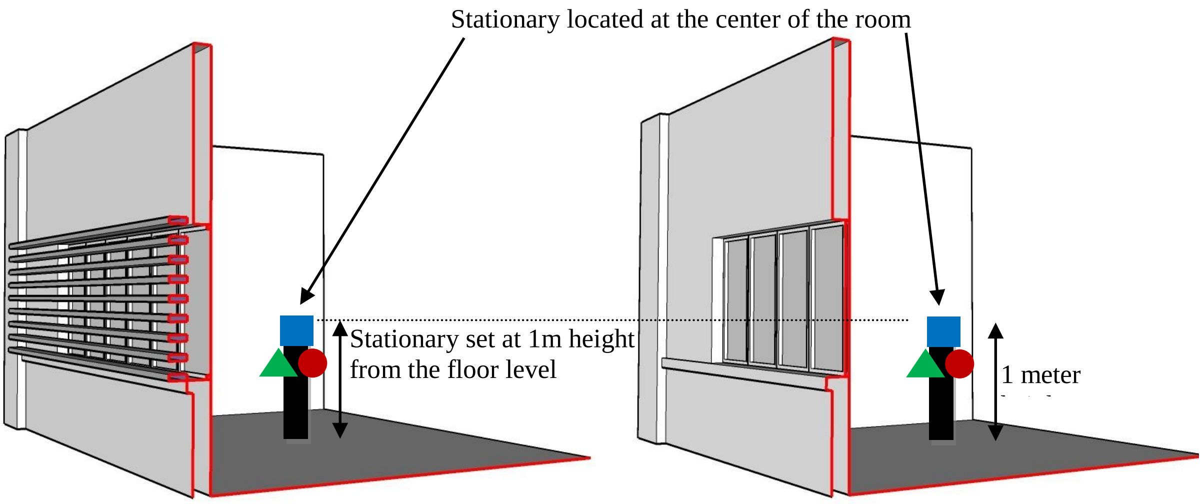

Fig. 4 - Sectional of the room installed with horizontal louvers sun shading and the control room (bare façade)

In advance of sufficient evidence being collected, the device was checked for accuracy in a single room with the same temperature and humidity. All the indoor instruments were positioned one metre off the ground in the centre of each room. A weather station also was set up using Onset Hobo U30-NRC to record background meteorological data such as ambient temperature, wind speed, wind direction, rain and solar radiation.

3. Results and Discussion

The outcome for the hot and bright day and the average significance result for the entire month were selected and discussed in the findings. Indicators of thermal performance are provided via statistics on intermediate radiation transmission (IRT), outdoor air temperature (T_o), indoor air temperature (T_a), and mean radiant temperature (T_{mrt}).

3.1 Intermediate Radiation Transmission (IRT)

The solar irradiance is measured between the windows and behind SDH during the experiment. SDH may minimize transmitted radiation behind windows. The performance of the intermediate radiation transmission (IRT) of the cooling effect indicator for the experiment is shown in Fig. 5. Significant cooling impact performance can be noticed on the highest average value on May 7, 2019. The control room reported IRT of 713.97w/m2, but SDH gave an excellent reading of 88.15w/m2. The result shows SDH can cut solar irradiance by 71%.

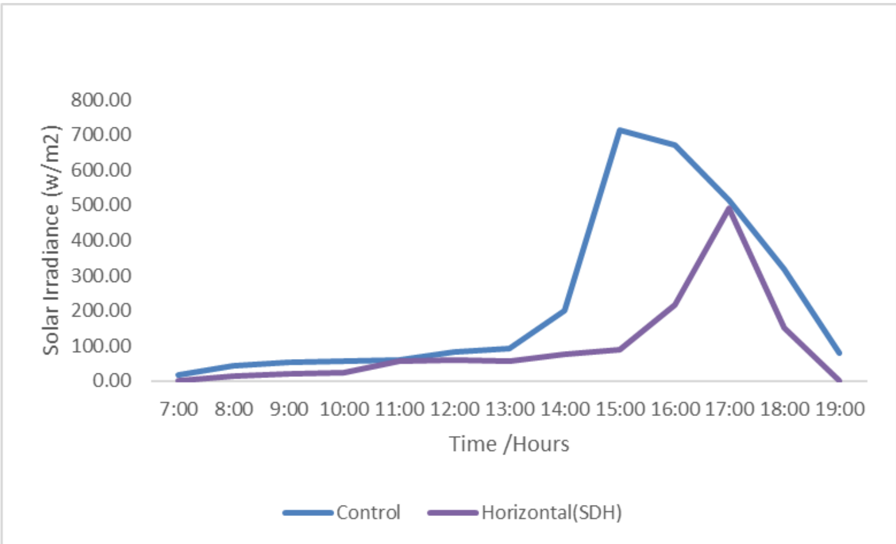

Fig. 5 - Comparison of the intermediate radiation transmission (IRT) on the highest value on 7 May 2019

The highest IRT on the average hours in the daytime from 0700 to 1900 of a month measurement (Fig.6) was 514.95w/m2 at 1500 in the control room. SDH reduced solar irradiation by 86.39 percent. The reading of IRT is greater in both experiment rooms owing to the sun orientation, which is the sun setting on the west side of the buildings in the evening.

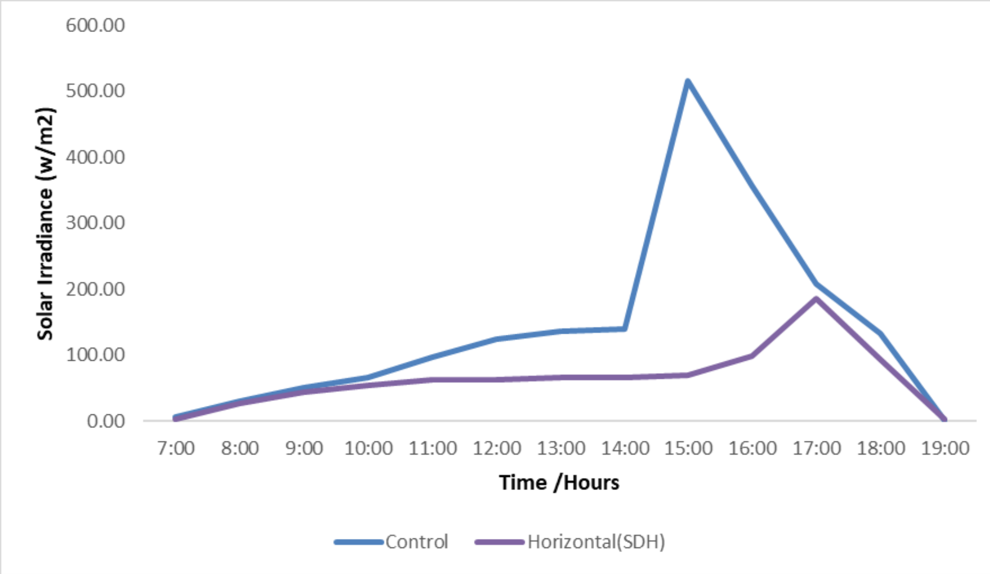

Fig. 6 - Comparison of the intermediate radiation transmission (IRT) on the average hours of a month

3.2 Outdoor Air Temperature (T*o*)

The temperature of the outside air is a driving factor behind natural ventilation. The stack effect is caused by the temperature differential between the interior and outside temperatures. Fig. 7 depicts the results of the comparisons between the outside air temperatures (T_o) generate by the room equipped with SDH and the control room without a sun shading device. The highest recorded throughout the 24-hour measurement was 36.12 °C at 1900 (7 May 2019) in the control room.

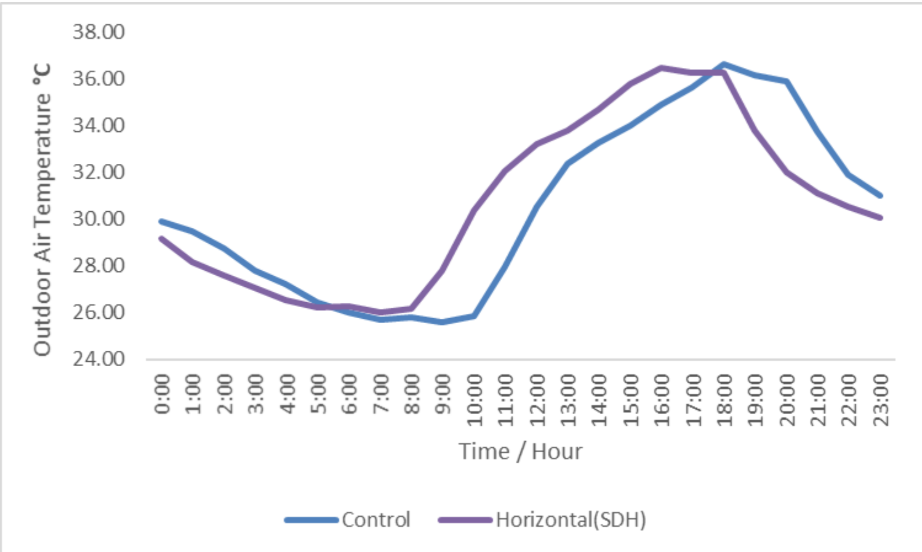

Fig. 7 - Comparison of the outdoor air temperature (T_o) on the average hours on 7 May 2019

SDH rooms fared the best in terms of decreasing interior air temperature by 2.86 K when fitted with fixed sun shading devices. Throughout the course of the investigation, the average temperature of the SDH room was brought down to 1.99 K, while the average temperature that was recorded in the control room was 34.04 °C.

The maximum ambient temperature (T_o) record in the control room was 30.32 °C based on a one-month average reading (Fig. 8). The consequences of a 0.19K increase in SDH room. The temperature rise indicated that the sun shading trapped hot air between SDH and the windows, which it progressively released overnight.

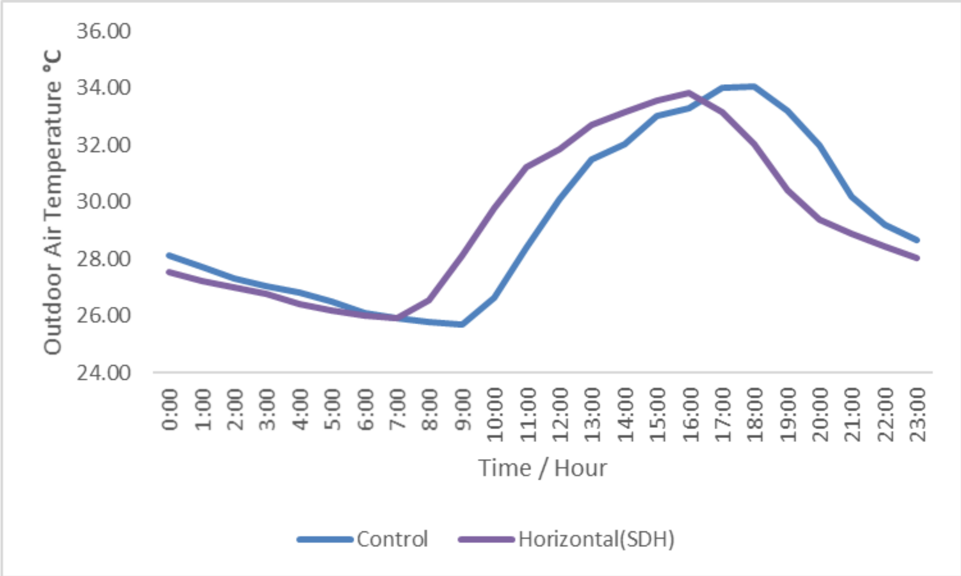

Fig. 8 - Comparison of the outdoor air temperature (T*o*) on the average hours of a month

3.3 Indoor Air Temperature (T*a*)

The most essential indication in determining cooling effect efficacy is the indoor air temperature. The more the temperature inside drops, the more effective the sunshade is at reducing the heat. Figure 9 shows the results of a comparison between the indoor air temperatures (T*a*) generated by the SDH-equipped room and the control room. The highest T*a* recorded during the 24-hour measurement was 39.20 °C at 1810 (7 May 2019) in the control room.

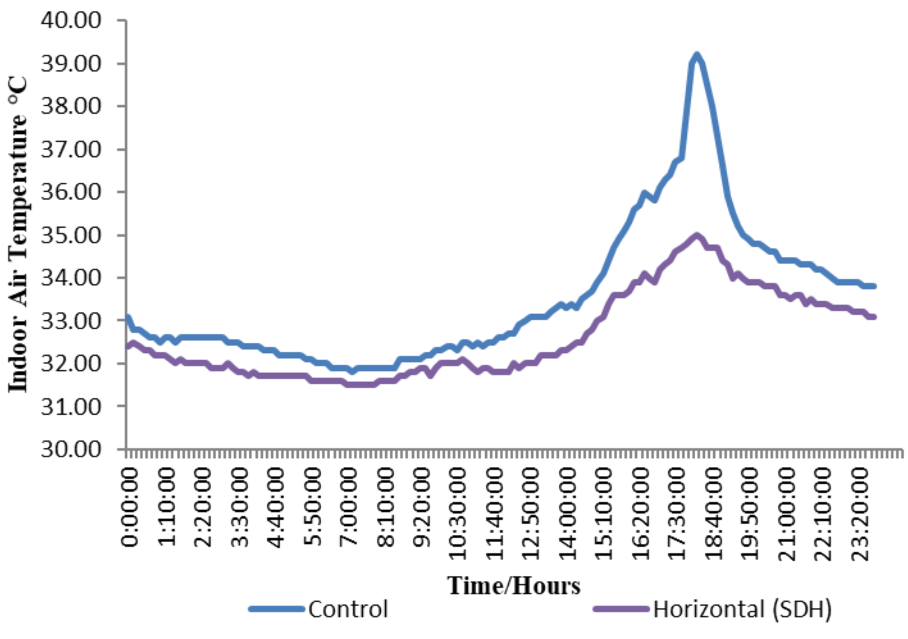

Fig. 9 - Comparison of the indoor air temperature (T*a*) on the average hours on 7 May 2019

The rooms with fixed SDH sun shading devices scored most effectively, with a 4.20K reduction in indoor air temperature. These rooms also had the most comfortable temperatures. Throughout the duration of the investigation, the temperature in the SDH room was brought down to 0.91K on average, while the temperature in the control room was measured to be 33.55 °C on average.

The maximum ambient temperature (T*a*) measured in the control room was 34.44 °C during the average hours of one-month observation (Fig. 10). The SDH room fared the best, with a drop of 2.32K. SDH performed fairly throughout the day, with temperature lowering producing the highest results at night. This discovery demonstrates that shading devices will have a major impact on the efficiency of the energy-saving process. As a consequence of this, the scope of this study could be broadened to investigate the impact that the variety of sun-shading device has on the efficiency of the energy-saving process.

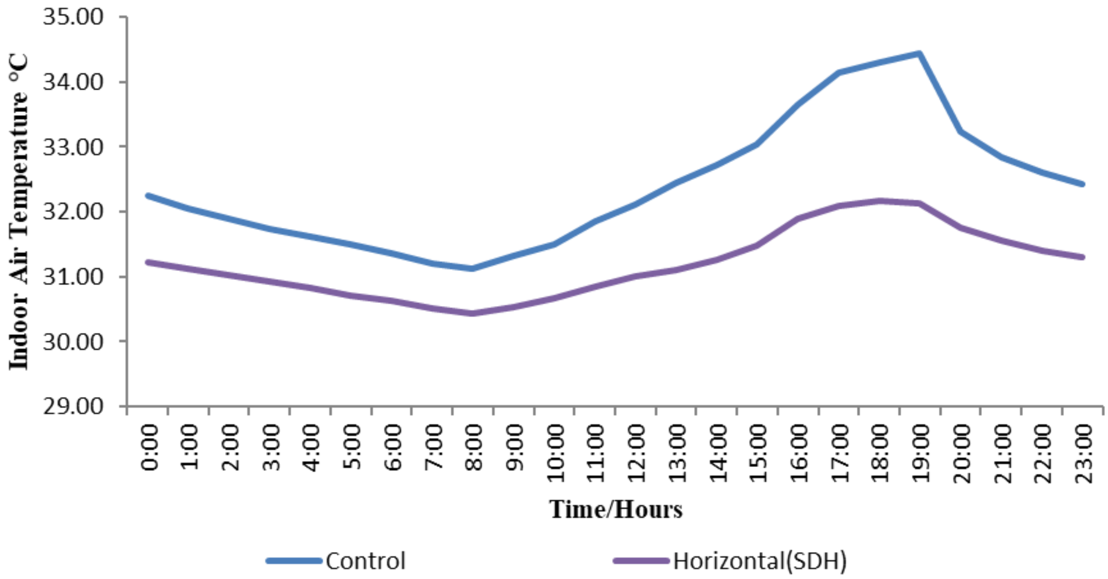

Fig. 10 - A monthly comparison of the interior air temperature (T*a*) generated by the sun shading performance

3.4 Indoor Mean Radiant Temperature (T*mrt*)

On a hot and sunny day (7 May 2019), the internal mean radiant temperature (T*mrt*) was greater than Ta. The maximum temperature was 40.90 °C, recorded in 1810, as a consequence of heat transported to the inside due to a lack of sun shield (control room). This passive approach has been shown to play a significant role in lowering T*mrt* as evidenced by the installation of sun shading devices. When compared to the control room, the SDH room fared the best in terms of lowering T*mrt* by 6.70 K.

For average T*mrt* within 24 h, SDH device performed superior in terms of thermal comfort (Fig. 11). The control room's average T*mrt* was 33.05 °C, and SDH was lowered by 1.29K. The fixed louver design of SDH enables airflow and heat dissipation through convection.

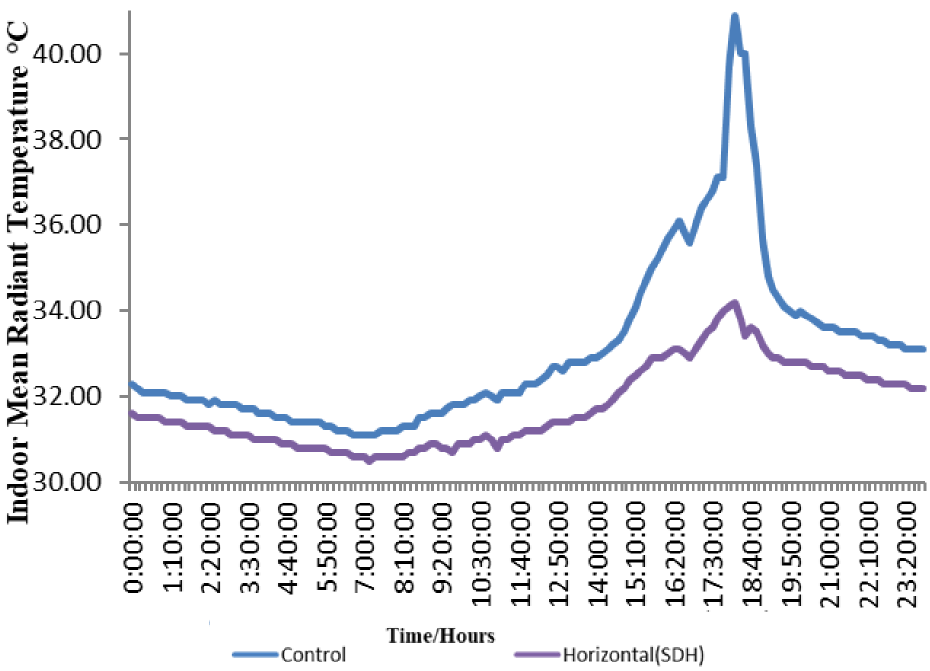

Fig. 11 - Sun shading effectiveness on May 7, 2019 was compared to the mean radiant temperature (T*mrt*)

The maximum mean radiant temperature (T_{mrt}) measured in the control room during the one-month investigation was 33.32 °C at 1900 (Fig. 12). The data indicate that SDH achieved the best results, with a decrease of 2.31 K. The average mean temperature (T_{mrt}) in the control room was 31.29 °C, with the best outcomes being achieved by SDH, with a decrease of 0.92 K. Based on the findings, it appears that SDH was most effective during the night time and mornings.. There is a possibility that the performance of the cooling effect of the interior mean radiant temperature will follow a pattern that is similar to the output of the cooling effect that the indoor air temperature will have.

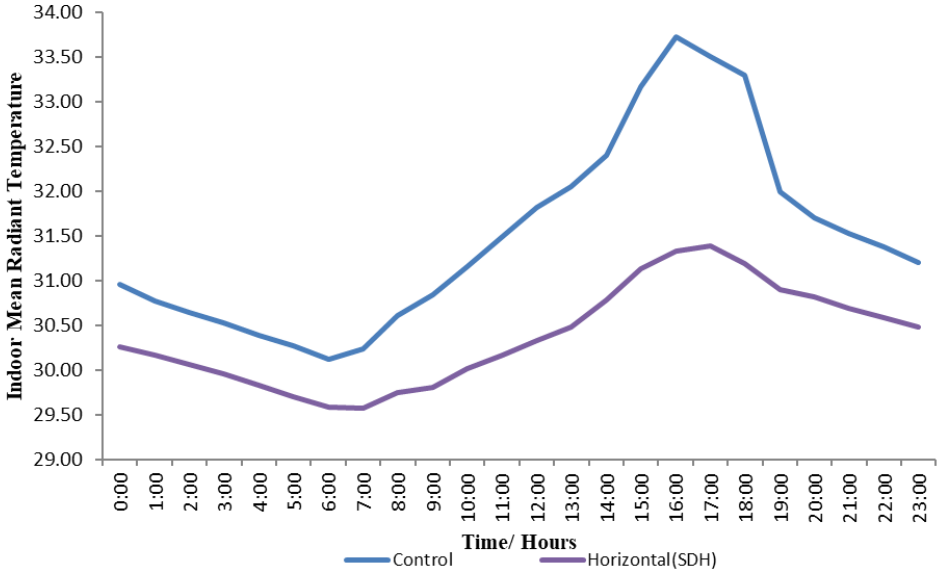

Fig. 12 - One-month comparison of mean radiant temperature (T_{mrt}) and sun shading performance data

4. Conclusion

Significant research has been conducted on fixed sun shading devices because they are one of the passive cooling systems that contribute to the overall performance of an indoor building's thermal environment. Majority of the research indicates that sun-shading devices are the most effective method for increasing the amount of available sunshine and the level of thermal comfort. The findings of this study highlight the significance of sun-shading devices as a viable alternative for regulating the temperature environment. However, the design and the type of material used in sun shading are the two most important factors in determining how well they block the heat. In this research, SDH fared the best in terms of lowering the heat on peak days and an average monthly basis. Even though the average outside temperature result is greater, the SDH may inferred to be the finest sun-shading system for lowering the inside temperature. In a room that relies on natural ventilation, the SDH system provides a higher level of thermal effectiveness.

Acknowledgement

The writers would like to convey their most sincere gratitude and appreciation to the Ministry of Higher Education, Malaysia, Universiti Kebangsaan Malaysia (UKM) (fund GUP-2018-0960), Universiti Tun Hussein Onn Malaysia (UTHM) and DML Products (Johor) Sdn Bhd for the cooperation and assistant during the research.

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